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Biotechnology in the Military

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ABSTRACT

Our world is undergoing a military revolution characterized by electronics, computers, communications, and micro information technology. Biotechnology is developing quite rapidly and has had an enormous effect on the progress of science and technology. It is a broad term used to describe technological innovation based on biology. It covers all aspects of living organisms, from medicine to agriculture. It is rapidly changing and growing. Biotechnology and the military are teaming up to help soldiers meet the challenges of needing quick mobility and different environmental background. Biotechnology offers novel opportunities for improving warfighter survivability on the battlefield. This paper examines the various uses of biotechnology in the military.

***KEYWORDS*:** military, defense, warfare, biotechnology

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INTRODUCTION

Biotechnology (or biotech) is a combination of biology and technology. So biotech is basically technology based on biology. Biotech involves not just a single technology but a wide range of technologies that share two key characteristics: working with living cells and having a wide range of uses that can improve our lives. It embraces a wide range of procedures for modifying living organisms to suit human purposes. Related fields include molecular biology, cell biology, microbiology, biochemistry, bioengineering, biomedical engineering, biomanufacturing, molecular engineering, and bioinformatics. The multidisciplinary nature of biotechnology is illustrated in Figure 1 [1]. The demand for new drugs is a major incentive for the explosive growth in the biotechnology industry.

Although the term "biotechnology" was not used until 1919, ancient civilizations used biological processes to leaven bread, brew beer, and ferment wine. There is no substance as important as deoxyribonucleic acid (DNA), because it carries the hereditary information that determines the structures of proteins. Once enzymes could be isolated, scientists could begin to direct the recombination of DNA and perform genetic engineering, which is the basis of the biotechnology industry. Modern biotechnology began in the 1970s after the development of genetic engineering that enabled scientists to modify the genetic material of living cells. Since the 1970s, when the first commercial company was founded to develop genetically engineered products, the biotechnology industry has grown rapidly. Knowledge of DNA sequences has become indispensable for biotech. All organisms are made up of cells that are programmed by the same basic genetic material, called DNA (deoxyribonucleic acid). DNA is made up of four similar nucleotides (designated by an organic base they contain, abbreviated A, T, C, and G). A genome is all the DNA in an organism, including all of its genes [2]. Biological sensing and analysis capabilities may extend to monitoring the health, safety, and performance of soldiers in the field. Biotechnology will have a large impact on the defense sector.

WHAT IS BIOTECHNOLOGY?

Biotechnology is technology that utilizes biological systems or living organisms to develop products. It is basically applied biology that forms the interface between biology and engineering. It is the one of the most rapidly growing field of technology today.

Biotechnology pervades almost all aspects of our daily life; it affects the foods we eat, the safety of the water we drink, the clothes we wear, the medications we take, etc.

Biotechnology can roughly be divided into three main parts [3]:

- *Green Biotechnology*: This involves agricultural processes. The foundation of green biotech is crop improvement and production of novel products in plants.
- *Red Biotechnology*: This involves healthcare processes. It uses the human body's own tools and weapons to fight diseases.
- *White Biotechnology*: This field is connected with industry and environmental processes. Most of the white biotech processes results in the saving of water, energy, chemicals and in the reduction of waste.

Popular biotech fields include [4]:

- *Genetic engineering:* This is the direct manipulation of DNA molecules to produce modified plants, animals, or other organisms using biotechnology. Through genetic engineering, organisms can be given targeted combinations of new genes.
- *Tissue culture*: This is a method where by fragments of tissue from an animal or plant are transferred to an artificial environment to continue to survive and function.
- *Cloning:* This describes the process (of breeding) used to create an exact genetic replica of another cell. There are three different types of cloning: (a) Gene cloning, which creates copies of genes, (b) Reproductive cloning, which creates copies of whole animals, (c) Therapeutic cloning which creates embryonic stem cells.

Humankind has used biotechnology in several areas such as agriculture, healthcare, environment, and industrial biotech. The relationships between these various applications are shown in the biotechnology tree in Figure 2 [5]. Figure 3 shows the classification of biotechnology sector [6].

MILIRARY BIOTECHNOLOGY

Biotechnology is an interdisciplinary field that combines biology, genetics, and engineering to develop solutions for defense challenges. For military affairs, biotechnology is developing at a rapid pace. It is playing a critical role in medical protection. Biotechnology and the military are strengthening the power of soldiers and resisting fatigue. It senses and monitors the battlefield. Human bodies could experience direct-effect weapons that would alter their biological features because biotechnology looks at a molecular level. Due to this, scientists can soon unlock ways to control, reconstruct, design, and simulate molecules in humans. Scientists could change cell functions as needed with the interaction of proteins. Figure 4 shows the 2024 convention on biotechnology [7].

The knowledge derived from the study of the genetic characteristics, molecular biology, metabolism, and biology of organisms promises to facilitate the design of devices, software, and genetically altered organisms. Modern biotech research has a focus on life structure's microcosmos. It is playing a critical role in the diagnosis and prevention of diseases, protection from biochemical toxic agents, and treatment of war injuries. Weapons created by biotechnology would be more destructive than conventional methods of the past, such as nuclear weapons and gunpowder.

APPLICATIONS OF MILITARY BIOTECHNOLOGY

Biotechnology is an engineering discipline that uses living systems to create a wide range of products. The technology can be used to produce an enormous range of things from food and medicines to textiles and fuels. It has many applications in the military. Although applications of military biotechnology are complicated, the finished products are convenient to carry, easy to use, and do not require large support systems. These applications that can support the rapidly emerging bioeconomy which can have significant benefits for national security. Specific applications include the following [8-10]:

1. *Defense and Attack:* Future combat systems of all types will be affected by biotechnology. Biotechnology can be used to develop new weapons systems that can be used for defense and attack. It is helping to reach all new levels of combat and helping large armies defend nations against adversaries of all sizes. The warfighter will undoubtedly be impacted directly by biotechnology innovations, including capabilities specifically related to improving force health protection and mission readiness. Optimizing warfighter performance will also include enhanced abilities to sense the environment.

Combat functions themselves may be modeled on natural, efficient biological processes.

2. *Treatment of War Injuries:* Biotechnology can be used to treat war injuries. Modern biotechnology has played an important role in treatment of war injuries, prevention and diagnosis of diseases, and protection. It is playing a critical role in the diagnosis and prevention of diseases, protection from biochemical toxic agents, and treatment of war injuries. Another game-changer could come from how soldiers heal in battle after experiencing an injury. Artificial skin could insulate soldiers from environmental extremes, as well as provide frontline treatment for wounds. Figure 5 shows a wounded soldier [11].

3. *Materials and Equipment:* Biotechnology uses biological processes, cells or cellular compounds to develop new materials, products, and technologies. It can be used to develop new materials and equipment for military platforms and infrastructure. It leverages unique properties of materials for military platforms and infrastructure, including those that are stronger, lighter, self-healing, less toxic, more efficient, and/or faster to manufacture than current alternatives. These materials can be stronger, lighter, self-healing, less toxic, more efficient, and/or faster to manufacture. Biomaterials could be used to develop new reagents for next-generation explosives, harvest rare earth materials, enhance armor protection, and develop specialized bio resins and polymers that offer increased performance in various applications. Modern biotechnology continues to advance the manufacture of bioderived materials through techniques such as enzyme engineering, cell-free reactions, and the expansion of classic fermentation-based technologies. Biological systems offer endless possibilities for the military to model synthetic materials. Figure 6 shows a scientist holding biosensing materials in a laboratory [9].

4. *Monitoring and Detection*: Biotechnology can be used to detect, identify, and monitor chemical, biological, radiological, and nuclear threats. Biotechnology can be used to sense and monitor the battlefield. Soldiers in the future will wear or carry sensors that can detect signature molecules in the environment, alerting them to changes that may be caused by enemy activity or influence. Sensors may provide early warning of an enemy intention to pollute the battlefield with chemical or biological agents.

5. *Biomanufacturing:* Biomanufacturing is the use of biological mechanisms in the manufacturing process. It is a process in which organisms and their biological systems are used to produce chemicals and biomaterials. It has been a part of the military industrial base since World War I. In its infancy, biomanufacturing relied on the availability of naturally occurring microbial strains that produced specific materials. Modern biomanufacturing combines a variety of disciplines, including engineering, biology, chemistry, and computer science, and facilitates the production of biologically derived materials on a commercial scale. Advancements in the fields of synthetic biology, artificial intelligence, and robotics have resulted in the rapid expansion of small-scale production capabilities. The processing of biologically derived materials is poised to revolutionize the way civilian and military sectors produce materials. The operations of a biomanufacturing plant can be separated into two phases: fermentation and product recovery. In the fermentation phase, sugars and other nutrients are converted into biomass and the desired product. In the product recovery phase, the alcohol is distilled and purified. Companies that focus on using fermentation to make products optimize both process development and strain performance. Building and operating large biomanufacturing facilities involve notable financial risk. Work is rapidly advancing that would introduce biomanufacturing processes for production of fuels, chemicals, and even construction materials. DoD develops biomanufacturing at home and with allies and partners to create a self-sustaining domestic biomanufacturing ecosystem.

6. *Supply Chains:* The supply chains have become burdensome and unwieldy, plaguing defense acquisitions. Biotechnology can make a significant contribution to addressing vulnerabilities in Department of Defense (DOD) supply chains. Recognizing its potential to revitalize supply chains, DOD recently named biotechnology as one of its modernization priorities. Defense planners must envision biotechnology products from inception through their full development and manufacture pathways that allow these technologies to be successfully shepherded. Initiatives from both the White House and DOD now promote the establishment of domestic supply chains that use biotechnology-based materials and biochemicals for high-value chemical precursors, military armor, energetics, and propellants.

MILITARY BIOTECHNOLOGY AROUND THE WORLD

Warfare has historically been the driving force for technology with numerous nations around the globe striving to develop the most advanced and innovative armaments to protect their domestic and international interests. A greater degree of visibility into the various biotechnology applications is being developed across governments and military organizations worldwide. Global military spending continues to rise year after year and the trend is not expected to stop any time soon. We consider how some nations are using biotechnology in their defense sector.

- *United States:* The US military maintained superiority in the area of science and technology for many decades. America's competitive edge makes it challenging for the US to deliver critical technologies. The Defense Advanced Research Projects Agency (DARPA) has investigated the behavior of insects and other animals in research for the Department of Defense (DOD). The principles of design, biosynthesis, and structure-property correlations in "living" materials and systems will be very important in determining new military applications of biotechnology. Thinking in terms of biological systems may not only provide solutions to specific problems, but may also provide clues to future opportunities. The US Army has declared biomimetics one of its primary focus areas for basic research [12]. Today there is a growing number of organizations that directly consider biotechnology capabilities and the issues that can affect warfighters. can affect the warfighter indirectly. The DoD must maintain a strong biodefense program to address the risks of deliberate use of biological weapons, with focus on great power competition with advanced adversaries China and Russia. Figure 7 depicts the collaboration between the Army and academic institutions [13].
- *Canada:* A Canadian company is working on "Quantum Stealth." They say they can hide where troops, artillery, tanks, and even buildings are hiding. It is not just the military that uses stealth. Predators in the animal kingdom rely on stealth to attack their prey. Asymmetric warfare is more suitable for cloaking or stealth technology. You could make another argument that stealth technology could lead to more peace. This is because smaller nations would not want to antagonize a power with a large military.
- *China:* China has spurred a significant increase in biotechnology research and development, with an anticipated increase of seven percent per year between 2021 and 2025. More specifically, China has made efforts to acquire international data that can facilitate assessment and control of health care for different countries. China's strategic investments in the United States are relevant as well. International companies that build facilities in the United States from the ground up are not subject to scrutiny. Although the construction, associated tax base, and potential job creation can be appealing locally, the risk to national security could well go unnoticed and unregulated. Consequently, near peer competitors could gather data about US technologies and citizens without being noticed. China has conducted "human testing" on members of the People's Liberation Army in hope of developing soldiers with "biologically enhanced capabilities," thereby creating biologically enhanced super soldiers [14]. PLA strategists believe that achieving "mental dominance" will be critical in future military competition across the spectrum from peacetime to warfighting. But Western scientists consider it unethical to seek to manipulate genes to boost the performance of healthy people. The People's Republic of China poses the greatest threat to America today. There are no ethical boundaries to Beijing's pursuit of power. Figure 8 shows some Chinese soldiers [15], while Figure 9 shows the asymmetry in ethics that exists between the West and China [16].
- *Russia:* Russia continues to invest heavily into human enhancement technologies (BHE). It has also led efforts to undermine global norms against the proliferation and use of weapons of mass destruction. Russia has dangerously increased the spread of disinformation about biological and chemical weapons, including during the war against Ukraine. There are concerns that Russia is considering further use of chemical or biological weapons in the future [17].

BENEFITS

Humaneness in the conduct of war has become the focus of attention recently, and weapons of mass destruction are banned to reduce casualties. Modern biotechnology makes it possible to combine two or more pathogenic genes and place them inside a susceptible living body to create a multiple-vulnerating effect. Future biobased technologies will undoubtedly create applications that cannot be predicted now. Other benefits of biotechnology in the military include the following:

- *Precision:* Biotechnology allows us attack at a more precise level. Injuries might be limited to a

specific gene sequence or a specific protein structure. Through gene manipulation, we can attack or injure one or more key human physiological functions (the ability to learn, memorize, keep one's balance, or even act aggressively) without a threat to life. Precision injury and damage are two vulnerating methods based on genomics and proteomics. They are completely different from traditional weapons of war that directly damage tissues and organs. Thus, current military biotechnology possesses a quality of "mercy."

- *Prevention of Diseases*: Biotechnology can be used to prevent and diagnose diseases. It can be used to protect against biochemical toxic agents. It can be used to help soldiers resist fatigue. Modern biotechnology maintains a rapid pace of development and plays an important role in medical protection.
- *Improving Materials:* Biological systems might also serve as models for improving materials for uniforms, particularly by reducing their weight and increasing their functionality. A soldier's clothing must protect against extremes of weather, chemical and biological agents, heat and humidity, and other factors.
- *Feeding Growing Populations:* The world in 2025 will be much more crowded, and resources will be at a premium. Biotechnology will provide a means of feeding growing populations. Many foods will be engineered to provide optimal nutrition and minimize spoilage. Therapeutics for treating chronic diseases using biotechnology-derived methods and products will be common. Vaccines will be available against most infectious diseases. With a better understanding of the basis of life, many of the painful conditions that afflict mankind in 2000 will be preventable. Although soldiers in 2025 will look outwardly identical to soldiers today, they will be stronger, have longer endurance, and will be more resistant to disease and aging.

CHALLENGES

Every organization that works with biotechnology faces unique challenges and needs. The challenges include the following:

- *Dual Use:* Biotechnology is inherently dual use, meaning it could be used both for legitimate and nefarious purposes. While the opportunities for combatting disease, cleaning up environmental pollutants, and harnessing scarce natural resources are positive outcomes, we should also be aware of the challenges and risks such as a rogue actor developing offensive biological warfare capabilities or the weaponization of pathogens to harm fragile biological ecosystems. As biotechnology advances and proliferates, the DoD will need to keep track of how various capabilities could be used for nefarious purposes, including deliberate attacks against populations and deployed forces.
- *Risk:* Biotechnologies may also be used in ways that pose risks to our armed forces, societies, and the environment. There are proliferation risks of new types of bioweapons created from accessible biotechnology research, including as fueled by generative AI. There is also unpredictable spread of biological agents with potentially irreversible impacts.
- *Fear:* As emerging technologies become more accessible, many in the Pentagon are concerned that adversaries might soon challenge or surpass American strengths. The democratization of biotechnology can enable adversaries to achieve technological parity. Some global competitors may be poised to achieve superiority.
- *Lack of Standardization:* Process development schemes are often considered lucrative trade secrets, but a lack of standardization in industrial process requirements continues to mean that ad hoc development can be an approach fraught with risk.

CONCLUSION

Biotechnology involves the manipulation of living organisms or their components to produce useful products. It includes the manufacture of products ranging from food-grade sweeteners to fuel alcohol, as well as the use of chemicals to modify the behavior of biological systems. Biotechnology is still an emerging field. Biotechnology and the military have exciting possibilities. Although biotechnology is one of the most versatile, exciting, and innovative technologies of the 21st century, its benefits for defense have yet to be fully explored. DoD seeds opportunities in biotechnology as part of its broader responsibility to ensure our enduring technological advantage, with significant implications for national security and economic competitiveness.

Biotechnology may be reaching a critical junction. As it continues to mature, proactive policy becomes necessary for the federal government to leverage emerging capabilities effectively and remain competitive. For more information about biotechnology in the military, one should consult the books in [5,12,18] and the following related journals devoted to robotics:

- Military Review
- Journal of Military Learning
- NCO Journal

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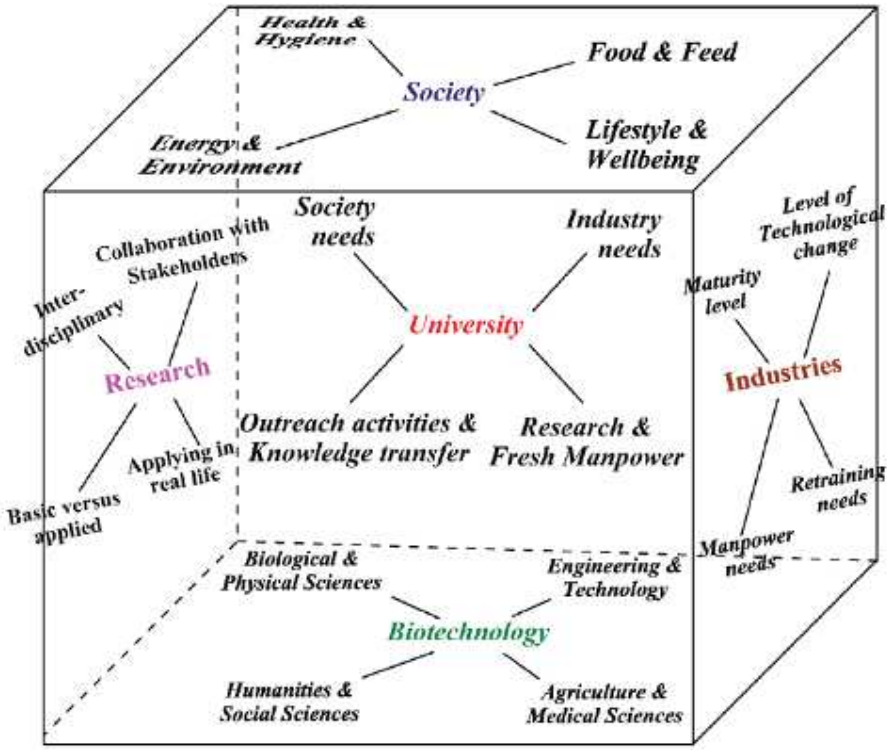

Figure 1 The multidisciplinary nature of biotechnology [1].

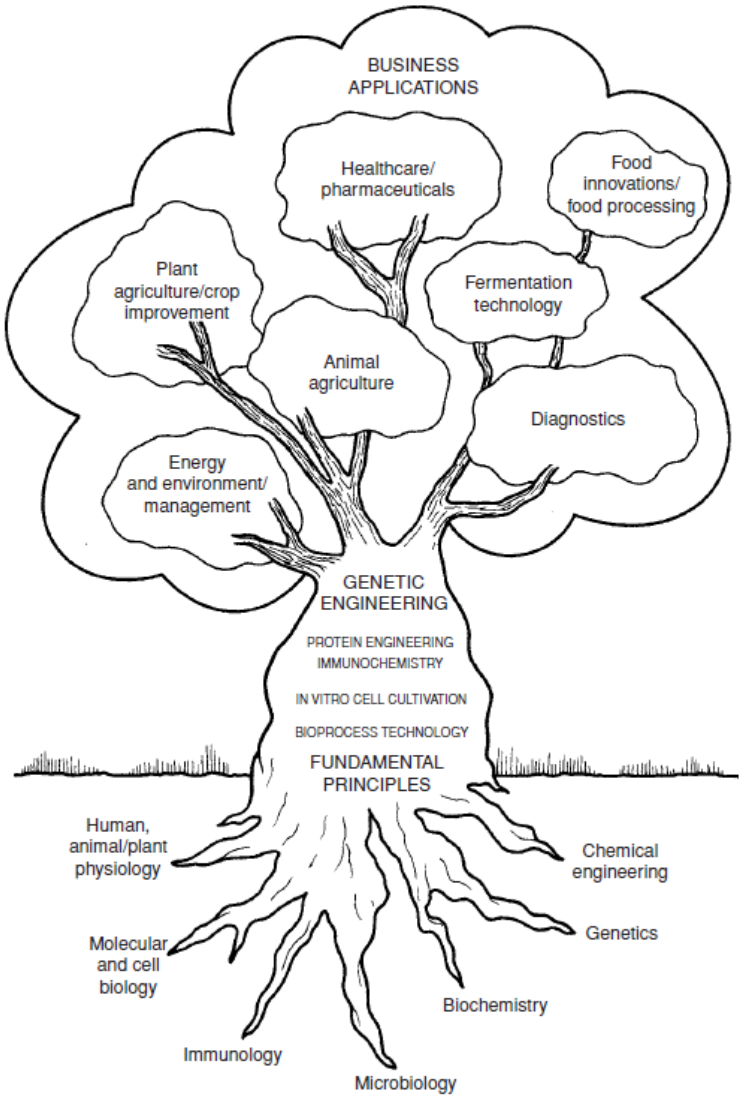

Figure 2 The biotechnology tree [5].

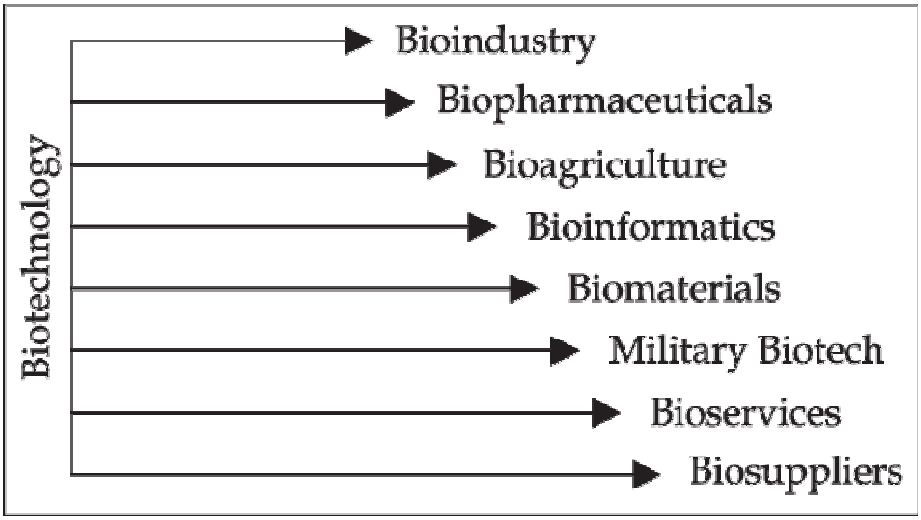

Figure 3The classification of biotechnology sector [6].

Figure 4 The 2024 convention on biotechnology [7].

Figure 5 A wounded soldier [11].

Figure 6 A scientist holding biosensing materials [9].

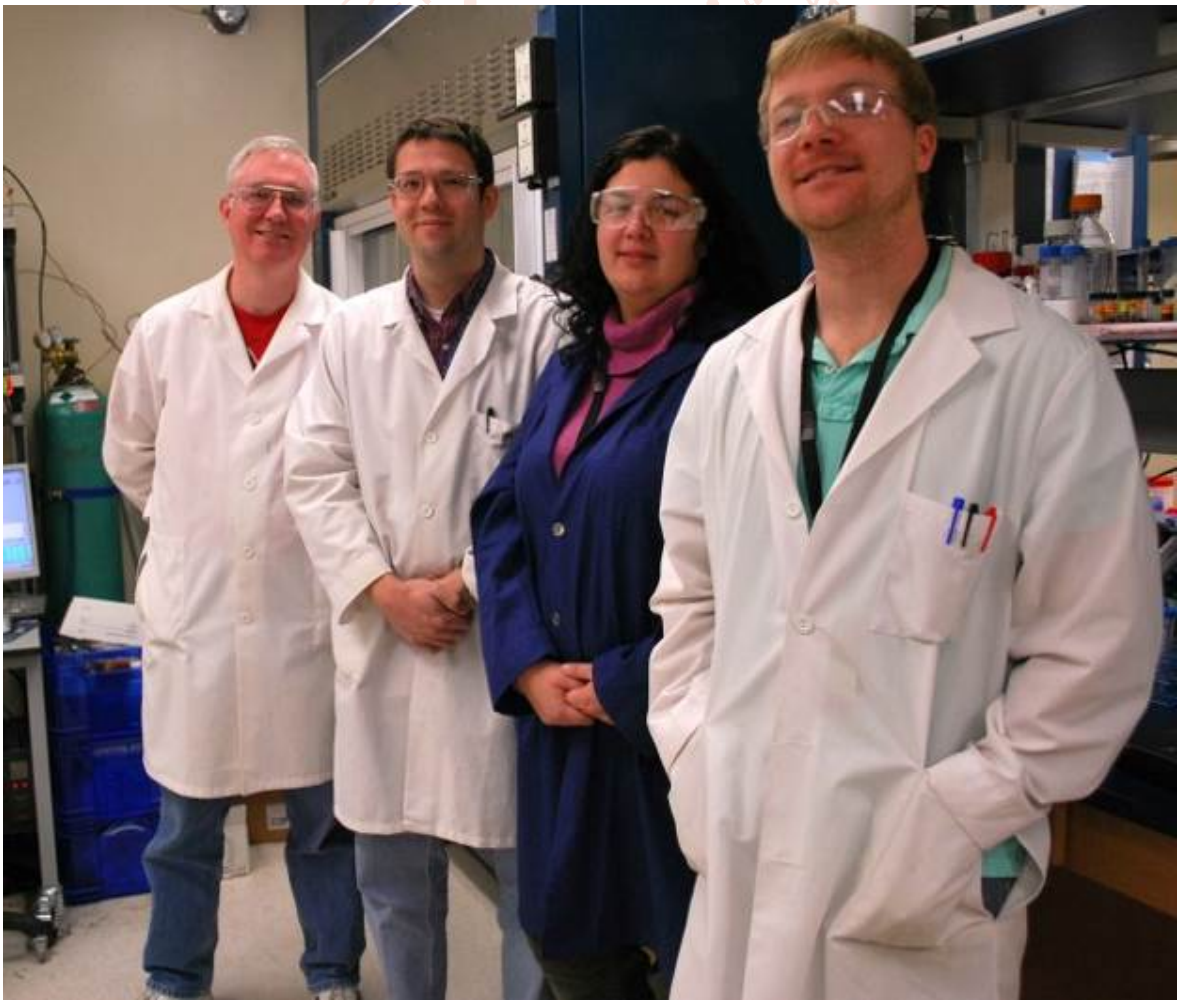

Figure 7Collaboration between the Army and academic institutions [13].

Figure 8 Some Chinese soldiers [15].

Figure 9 Asymmetry in ethics that exists between the West and China [16].